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CONTRIBUTIONS TO THE PHYSIOLOGY AND BIOLOGY OF THE DUGONG

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THE accounts of the habits of the dugong that have hitherto been brought to the notice of naturalists are really limited to a detailed description by Klunzinger, who as surgeon on the "*Koseir*" in the sixties, collected these accounts of the dugong of the Red Sea from the Bedouins. The account in Brehm's *Tierleben* is taken from him. The few who before or after him have had to do with the subject, have added but little that was new. For this reason we are warranted in publishing some very recent observations based on the field notes of one of us (Dexler). In 1901, through the generous support of the Gesellschaft zur Förderung deutscher Wissenschaft, Kunst, und Literatur in Böhmen, Dexler was enabled to make a visit of several months to the Coral Sea, and there to attend personally to the capture of the dugong. Incidentally, also, the rare opportunity was afforded of observing minutely for forty-eight hours the habits of a captive dugong, and to investigate in life what has hitherto been impossible for us to find out in the case of this animal.

The low flat coast of East Australia is a favorite haunt of the dugong. Here are broad, shallow bays choked with sand and covered with water at low tide, and connected with the outer ocean by numerous channels and passages. Here is the plant-bearing sea bottom on which occur the so called "dugong grasses" that constitute the food of the dugong. These bottoms are the chosen pasture of the dugong and it is one of their permanent occupants, being directly dependent for sustenance upon places of this sort. Wherever there are these conditions, to which must be added sea water and a particular temperature, there the dugong will be found as all observers agree (Ruppel, Klunzinger, Finsch, Semon). Sea water is its native element and it is questionable if it occurs at all in brackish water at the mouths of rivers, as is maintained by many, *e. g.*, Brown. But as Finsch has stated, observations on this point are lacking, and we ourselves observed nothing of the sort. It is not known by the old Queensland dugong fishers to enter brackish water, and that it seeks the fresh water of the river itself is out of the question.

During the day the dugong remains in the deeper waters of the outer ocean and only at night comes in through the channels previously mentioned to feed in the bay. This observation is corroborated by those of Klunzinger in the Red Sea, and by the statements of Semon and Finsch. With regard to its appearance at night, Klunzinger makes a noteworthy statement based on the accounts of the Bedouins. According to them the dugong is recognized at night not only by its "blow" and by the phosphorescence of the disturbed water, but also, they asserted, by three shining spots on the back, a fact of which he was repeatedly assured but which he found it difficult to believe. Krauss attributed this to the luminosity of the sea, but by Brehm it is explained as due to the sparkling in three places of the water that is disturbed in swimming, and thus made luminous. These three places would correspond well to the rounded ripples that would be made by the head, the middle of the back, and the caudal fin. Langkavel also cites Klunzinger's statement. No such phenomenon was observed in the Australian waters, a fact that may have been in part due to the slight degree of phosphorescence of the surface water at that time of the year (the Australian winter). However, in spite of the bright light of the tropical sea, it is highly probable that this is a faulty observation, and untrue of the dugong. For as it swims, its head first appears above water to take breath, rarely the back follows, while the tail is never shown. These movements might very well produce a more or less clear flashing when the water is strongly phosphorescent, but it would seem quite as impossible to identify the animal by this as to tell it by the noise it makes in breathing. Dexler hunted the animals in waters inhabited by both dugongs and dolphins, and in the tropical nights made careful observations for many hours while lying in wait at the nets in their pursuit. At no time, however, was it possible to distinguish the two by their resounding "blow" though often they were extremely near at hand. Moreover, the blackfish hunters were questioned in regard to this point, and although they are extraordinarily expert in whatever has to do with the pursuit of their quarry, they were unable to distinguish between the sounds produced by the breath of these animals.

It is well known that the movements of the dugong in swimming are slow and clumsy (Klunzinger and Finsch). Thus late one evening Dexler observed from his boat, six dugongs that lazily broke water scarcely ten meters away, and with a forward rolling movement disappeared again. As a rule, only the nasal portion of the head came above water in taking breath as Ruppel also has observed ; but Ruppel and Semon likewise agree in stating that very rarely the anterior part of the body or the entire head may appear.

Before proceeding to describe certain peculiarities of biological interest, we may add the important observations made on a captive live dugong that have furnished the basis for the systematic treatment of the biological material to follow. More particular details as to capture will also be given shortly.

On one occasion when the nets were examined, there were found in them a large ray, an ocean-butterfly, and a dugong whose tail had become entangled in the net, though otherwise the animal was able to move freely. This might be called very unusual, for the animals generally strike the net headfirst, or with one of the flippers, getting entangled, and while hanging in the net they thrash and roll about until they are completely entangled by the cords. The heavy net is thus drawn together into a solid mass and the dugong, no longer able to raise it in order to come to the surface for breath, is drowned. In the present case, as the net was tightly drawn together, it could not be pulled up on the spot, and it was decided to drag the whole thing out onto the shore, with the captive in tow. The fast cutter had some difficulty in pulling the animal, but despite its tremendous struggles it was towed along after the boat, tail first in the gurgling wake. Twice the boat was stopped in order to allow the exhausted bull to obtain air, and on these occasions it became very excited and unmanageable. It kept constantly trying to dive, jerking its arched body into the deep, and when it felt the pull on its tail it rolled over and over on its long axis two or three times. Repeatedly during these movements, it voided gaseous and solid excrement which diffused the characteristic odor of the dugong. The captive came up to breathe at intervals of from 14 to 42 seconds, exhaled with a long and forcible "blow" and inhaled with less noise and more quickly. Then the diving and rolling were repeated.

With the flood tide the boat was brought over the bar to the mouth of the Wallumkreek and there anchored. Here in the shallow water the animal became for the first time somewhat quiet after the people had withdrawn, but when the dingies put off from land again and approached it, straightway the diving and struggling began anew. From this it seemed that it was not so much the sight of the approaching boats as it was the sound that acted upon the animal's consciousness. If a black cloth or a piece of white canvas were waved above its head, the animal was not visibly disturbed or only rarely. But if one stamped on the deck then immediately it thrust its nose into the sand in a reflex diving or escaping movement.

It was a simple matter to secure the dugong, for the helpless animal had hardly more than its great weight with which to oppose its capture. A strong line was soon tied about its tail and made fast to the shore, and the dugong was then rolled out of the net into the water. There it appeared to feel better and began at once to thrash clumsily about, and tried to hide underneath the cutter. However, the strain on the line soon relaxed and with but slight exertion the dugong could be dragged into shallow water. By this time it put its snout above water for breath at intervals of from 17 to 65 seconds and breathed in the manner above described. If anyone spoke, or struck the tiller, or rattled the anchor chain, or made any other noise, the dugong started off violently and tried to dive deeper with a movement like that of the dolphins that roll head foremost over the surface of the water. In these attempts the animal repeatedly struck the sand bottom with considerable force. As soon as the line drew taut and the dugong felt the pull, it at once executed those remarkable rapid revolutions on the long axis of its body so that the line began to crack. When the noise ceased, the dugong soon became quiet and lay motionless at the bottom, resigned to its fate. The intervals between breaths also became longer; at first they were from 43 to 60 seconds, then later, from 100 to 120 seconds apart. The following intervals were particularly noted: 104, 43, 60, 58, 95, 45, 105, 145, 85, 52, 50, 56, 120, and 85 seconds. The longest interval was 145 seconds though of course it must be kept in mind that in this case the animal was living under abnormal conditions, of which it must have been sensible, despite its partial freedom. The exhaled air had the same aromatic odor that is peculiar to the flesh, the excreta, the fat, and the steam from the boiling meat.

Thus the captive was studied for a number of hours, though but little else was brought out, for the radius of movement of which it availed itself was very small. Such observations as were made, however, were concerned almost entirely with the breathing. If one struck the animal with the tiller, it took each stroke with a slight shudder of the entire body. A more delicate sensitiveness of the skin could be made out at the corners of the mouth only. If one touched this region with the thumb, the dugong suddenly raised its head a hand's breadth from the bottom.

At evening the animal was rolled up onto the shore. During this process it thrashed about but little and allowed itself to be borne to land as quietly as a barrel. Not until it was choked did it repeat the tremendous strokes with the tail; at other times it moved neither the hinder part of the body nor the flippers. The latter were held against the breast, but if they were pulled away from the body, they remained in that position. For forty-eight hours it lay motionless. Its death was easy, for it was asphyxiated by quickly thrusting two gun wads into the nostrils during an inhalation. It raised its head, gave three mighty strokes with its tail and expired.

After this description, necessitated by the nature of the case, the biological details will again be systematically discussed. A little has already been said in regard to the manner of inspiration and expiration. Both processes take place out of water and exclusively through the nose. When the captured dugong was asphyxiated by closing its nostrils, it made no attempt to open and breathe through its mouth. These conditions in the dugong, it is interesting to observe, correspond exactly to those found elsewhere in which the epiglottis is behind the velum or in front of it, and thus does not permit of a supplementary breathing through the mouth also (see Boenninghaus, :03, p. 84). Still, a similar topographical relation of the parts in question does not correspond to similar physiological phenomena, since in the Sirenia the velum palatinum and the epiglottis are very short (dugong, Owen, '38, p. 36; manatee, Waldeyer, '86, p. 245; Murie, '70, p. 178).

The dugong takes breath quickly, closes its nostrils, and sinks into the water. The closing results from the fact that the base of the nostril is raised as a slight eminence and pressed tightly against the top. It is interesting to observe that this procedure was also kept up while the animal was lying on the shore, and after each inspiration the nostrils were fast closed until the next breath was taken. According to Finsch, the closing of the nostril takes place through the action of a muscle which he does not indicate further. Ruppel ('34, p. 101) makes the incorrect statement that the nostrils can be hermetically closed by valves opening inwards and this fallacy is repeated by Brandt ('46–'69, p. 272). It is worthy of note that Turner ('94, pp. 319, 322, 326) found in the embryo and in the head of an adult dugong, valves ("valve-like flap," "plug-like valve"). No trace of such a valve can be demonstrated. The same structure, it has been claimed, has been found in the manatee. Brandt has previously asserted that in the Sirenia "aperturae nasales valvulis claudendae esse." Garrod ('77, p. 139) plainly speaks of a "flap valve" which forms the base of the nasal passage during the act of breathing but rises and completely closes the nostrils when it is shut. Likewise Brown ('78, p. 292), Chapman ('75, p. 461), Crane ('81, p. 457), and Noack ('87, p. 297) speak of a valve. Murie ('80, p. 32) had already rejected Garrod's statement and described the arrangement in the manatee as similar to that in the dugong, that is, that the base of the nostril is raised by contraction of a circular muscle and the opening is thus closed and that a free valve is out of the question.

In expiration there is a perceptible sound, that has been described above as a loud, long "blow." Klunzinger calls it a puff, Finsch a breath and a puff. Semon speaks of it as a singular hollow puff. Moreover, it is not accompanied by a discharge of vapor.

The increase in the length of the intervals between breaths, given above, is of interest. It is of course quite possible that the conditions of living and of breathing incident to the animal's long period of captivity were extremely abnormal, so that it is difficult to learn from them precisely the normal conditions. Nevertheless, we cannot be far wrong if we take as the average time between breaths a minute or a trifle less. The accounts of writers show great disparity on this point. Ruppel states that the dugongs come to the surface about once a minute. According to Klunzinger they do so every ten minutes and always about four times. Semon observed a large male that came up at intervals of from three to five minutes, and Finsch agrees as to these longer intervals. However that may be, it should be observed that the longest interval between breaths noted by us did not exceed two and a half minutes.

The dugongs, as above noted, feed chiefly by night and the same is also true of the manatee. To be sure, Noack ('87, p. 300) writes that they eat all day long without interruption, though Brown ('78, p. 295) had previously shown that as with nocturnal animals in general, they appear to feed at night only (see also Murie, '80, p. 24). The food and the feeding habits of the dugong have hitherto received very meager treatment. The animals lie, it appears, directly on the sea bottom, and with their thick lips graze leisurely upon the seaweeds (sea algæ, according to Ruppel) that grow on the rocks or the sea floor, or they tear them from the bottom. Klunzinger speaks of sea plants, phanerogams (Niades). According to Finsch and Semon it is chiefly sea grasses and species of Fucus, according to Fairholme, "grass-like seaweeds," that constitute the food supply. But it may be stated that the food of the dugong does not consist of the thick, dark brown seaweeds floating up free from the bottom, but rather of the two green phanerogamous plants which were present in the stomachs of all the dugongs killed, unmixed with any other vegetable remains. The dugong fishermen employed by Dexler paid no attention to the beds of thick, dark brown seaweeds that could be seen growing up from the depths, but kept a sharp and constant watch of the clear sand that was almost without vegetation. There only were traces of the dugongs to be found, and never in the rank forest of seaweeds.

At our request Professor Aschersohn of Berlin, had the kindness to examine the species of plants found in the stomachs of the dugongs, and determined the one to be *Halophila ovalis* (of the Hydrocharidaceæ) and the other a species of Zostera (*Zostera capricorni* Aschersohn). The latter grows as a dense or scattered low bed, while in Halophila the root stalk and petiole are hidden in the sand and only the small leaflets project slightly. These two plants do not occur on rocky bottoms. The Halophila growth is limited to a depth of about six meters below the low tide mark; higher up, the growth becomes sparser until it entirely disappears. The white sand, peculiarly flecked and spotted by the Halophila leaves, is the especial feeding place of the dugong. The slight depths at which the dugong's food plants can grow also explain why the animal spends part of its life in the shallow seas and part in the off-shore waters.

Among the beds of Halophila are the so called dugong's tracks which at once show us how the animal takes its food. The tracks are long, curved, or wavy furrows in the white sand, with sides parallel, about four fingers broad and from four to six cm. deep. They are completely denuded of the Halophila. Their age is determined by the condition of their edges; fresh tracks have raised, sharply defined edges rising from one to two cm. above the sea bottom. If the strong flood tide has swept over them once, the sand becomes washed away, the edges obliterated, and the depth less, until finally they are entirely washed away. These furrows, showing white through the dark water, indicate the presence of the dugong. They are produced by the dugong passing over the Halophila beds as it feeds, pulling up the plants with its palatal processes, seizing them and perhaps washing them free of sand and other extraneous matter after the manner of certain waterfowl (ducks), and then chewing them up with its molar teeth. The dugong trails are not made up of separate marks which would indicate that the food is not plucked or bitten off in tufts. Such plainly continuous trails could not be made by the animal's lying sluggishly at the sea bottom. Also the peculiar lateral mark made by the tusks[1] in case of the male is explained by the method of feeding just described which necessitates their active share in this process. Finsch, however, speaks of dugong tracks that were found on bars left more or less dry at low tide and could be readily recognized by the cropped sea grass, the disturbed bottom, and the imprints that were left by the animals' bodies. The first of these marks is established by the description preceding, but we may very well doubt whether the last is possible. Nothing of the sort was certainly observed in Moreton Bay, Sandy Straits, Wide Bay, and the northern Coral Sea.

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[1] Finsch believes that the tusks serve for uprooting the sea grasses rather than as weapons, but the fact that they are lacking in the females, argues against this view.

There can be no doubt that the sensitive upper lip plays an important part in the taking of food. We know from the numerous careful observations made on living manatees in aquaria (we may mention only Brown, Murie, and Noack) how extensively these animals use the upper lip in feeding. It is unnecessary to lay particular stress on the fact that the food plants of the manatee are considerably different from those of the dugong because of their different habitats. The feeding habits of the dugong, as described, likewise differ in a general way from those of the manatee.

The washing of the food plants in the mouth must be very thoroughly done. Moreover, the dugong in its progress stirs up a quantity of sand and other inorganic particles but for all that, matter of this sort is seldom found in its stomach contents.

It has been previously stated that the captured dugong while being pulled ashore, voided excreta and intestinal gases with the characteristic dugong odor. It likewise did the same while lying hauled out on the land. The fæces were rather solid, cylindrical, and greenish yellow to greenish black, aromatic but not fœtid; in the water they sank at once. Brandt ('69, p. 235) on the other hand, states that the intestinal contents of the Sirenia are strongly fœtid, that the excreta float on the water, and are similar in form to those of the cow or the horse. Chapman ('75, p. 460) records that the fæces of a captured manatee that appeared to be suffering from constipation, were very hard, and that a constant stream of gaseous bubbles was given out from the anus. Murie ('80, p. 22) in case of his manatee merely mentions the droppings. Noack ('87, p. 300) on the other hand, states positively that the excreta of *Trichechus senegalensis* appear greenish brown and rather formless, and that they are usually seen in the water only. Brandt's description agrees with neither the dugong nor the manatee. The urine of the dugong is clear as water.

Unfortunately no exact observations could be gathered as to the temperature of the dugong. The captured specimen, when brought out on land grew remarkably cool. The rectum showed a temperature of 19° C. Immediately after its death the thermometer was thrust into a cut made towards the base of the heart. The dark red blood, laden with carbon dioxide, that gushed forth had a temperature of 17° C. One can therefore hardly express an opinion as to the normal temperature of the dugong, especially as the temperature of the air (taken by whirling the thermometer under a clouded sky) was from 12° to 18° C., and the animal had lain motionless for 48 hours. In addition the heavy body, weighing some 192 kilograms, pressed the easily fixed sternum hard against the heart, whereby the activity of the latter, the blood circulation, and consequently the body temperature must have been very much disturbed. The marked increase in the interval between breathings is also evidence for this. The beating of the heart could not be detected either by its palpitation or by auscultation. This dugong impressed one as an animal that had become cooled off, and whose temperature conditions (irrespective of its abnormal position on the shore, and the unusual pressure) were so sensibly disturbed that it had lived only a short time after being taken from the water. Moreover, observations on manatees taken and kept in captivity, show that almost always changes in temperature are the cause of the sickness and death of the animals (Chapman, '75, p. 461; Murie, '80, p. 23; Crane, '81, p. 460).

No voice or production of a sound on the part of the dugong could be detected beyond the blowing already mentioned, that accompanies exhalation and inhalation and it is similar to that of the dolphins. Finsch leaves the question open as to whether or not there is a real voice. The earlier writers speak of a hollow moan or snort in the case of adult animals, and of a short, sharp cry frequently repeated on the part of the young (Brandt, '69, p. 235). However, Brandt thought all these sounds were produced by dying animals only, for Steller likewise stated that the uninjured rhytinas never uttered a sound, while the wounded ones gave a sort of hollow moan. Also in the case of the manatee no trace of a voice has been observed (Murie, '80, p. 22) though Murie believes that this may be different under other circumstances. Nevertheless it is to be remembered that the Sirenia have no vocal cords and that therefore sounds or noises may perhaps arise through vibrations of the laryngeal cartilages and should thus presumably take their course out through the nose.

As regards the activity of the sense organs the dugong as well as the manatee has reached a considerable degree of development. To many sense organs we are unable to assign a very definite function. This is true of the senses influenced by chemical stimulation, particularly the organ of taste, although as Gmelin ('92, p. 18) has shown, a taste organ is found in the manatee in the form of a so called papilla foliata. The care shown in the selection of food likewise points to a certain taste function. It is still more difficult to demonstrate the function of the organ of smell since the olfactory region is a nasal tract that is hermetically closed when under water. And yet Chapman claims that in conformity with the well developed bulbi olfactorii, the sense of smell must be very keen, for it was observed that his captive manatee seemed to become aware of food thrown in the water through its sense of smell rather than by any other sense. Brown ('78, p. 295) says the same, referring to Chapman.

Boenninghaus (:03, p. 91) has pointed out that mammals that seek their food in the water, can make no use of their sense of smell in obtaining it because the nose is tightly closed in diving. Even if this were not the case, he continues, mammals would still be unable to smell under water since the necessary stimulus for their olfactory nerves consists of scent particles which are held in suspension in the air and not, as with fishes, those that are suspended in the water. The disuse of these organs in the case of whales has led to their partial atrophy or total disappearance. Thus in the toothed whales the olfactory nerve is lacking, and correlated with this is the reduction of the exethmoid bones. In the Sirenia, however, in spite of a reduction in this bone, an olfactory nerve and bulbus are well developed, and this, too, notwithstanding the objections just mentioned to the possibility of a smelling function. This possibility becomes a probability if not a reality by the observations on the manatee given above. From these observations it follows that in the Sirenia, at least, there is no connection between the reduction of the exethmoids and that of the olfactory nerve as there may be in case of the whales. It is also clear that the olfactory nerve as a functional structure must be capable of perceiving chemical stimuli that utilize water as the carrying medium instead of air as with land mammals. This assumption, of course, implies not only a partial functional adaptation of the olfactory nerve but it also limits such an adaptation to the herbivorous Sirenia alone. Finally we must also assume that the chemical stimulus, since it cannot reach the olfactory membrane in the usual way, must take another course, perhaps by way of the mouth, pharynx, and choanes.

One more observation on the reflex irritability of the nasal membrane may be added here. Before the death of the captive dugong, Dexler endeavored to squirt water into the animal's nose as it drew in a breath. Instantly there came so violent an expulsion of the fluid — which had barely entered the nostril — that it was blown into a fine spray. The reflex was astonishingly violent and quick, and after it had taken place the nostril openings were fast closed as before. Thus the breathing movement that had been begun, was not completed. Surely so prompt a reaction is of the greatest importance for aquatic mammals. The action by which the nose is closed in case of the dugong is thus two-fold: voluntary and reflex. Water pressure as an aid is not necessary, or at least only auxiliary.

The dugong's sight must be characterized as rather poor. Otherwise it would be impossible to capture the animal with so roughly constructed a net, as is actually done. Nets from 80 to 150 meters long and from 5 to 6 meters deep are so disposed over the dugong's feeding grounds as to form a vertical wall. If a dugong comes in contact with the net, then it is usually all up with him; but a dolphin or a shark is never captured in so simple a manner. To be sure, the dugongs avoid the nets more easily on clear nights and for this reason the best time to take them is during the nights of the new moon. The cords of the net are colored brown also. But if one is lucky he may capture the animals during the full moon as well, and even with new nets of shining whiteness. A further proof of the poorly developed vision is the fact that the captive dugong did not notice very much the waving of a white or a black flag and that not infrequently no notice was taken by the dugongs of the noiseless approach of the boat so that it was possible to observe these animals at very close quarters. Semon has remarked the same thing and the fishermen employed by Dexler asserted that they had repeatedly sailed right over feeding dugongs. This might be due, however, to the fact that it does not seem particularly shy (Semon) or that it is but little concerned for its own safety (Finsch). Feebleness of vision has likewise been recorded in case of the manatee (Chapman, '75, p. 454; Brown, '78, p. 295).

Investigation of the eye in case of our captive dugong was very difficult and therefore inadequate. For in order to do this one must lie directly beside the animal on the sand, and as may be readily seen, this is, to say the least, disconcerting when one does not know what movement the creature may make next. Moreover, the focal illumination was considerably hindered because the bulbi were deep set and constantly held pointing slantwise forward and downward, and the slit between the eye lids was narrow. Furthermore there flowed from the conjunctival sac such a quantity of tough, stringy secretion that the eye opening was constantly obstructed as with a thick plug.

This had first to be removed and the short intervals before its re-formation were utilized in a rapid study of the front portion of the eye. It was impracticable to expose the bulbus by opening the eye lids with one's fingers for these were closed tightly at the slightest touch. If they were forcibly pressed apart the nictitating membrane was then pushed up and the bulbus retracted in such a way that it disappeared under the membrane and the periorbital masses of fat that were forced forward. After five or ten minutes there appeared at the bottom of the fatty funnel thus formed a bit of the cornea like a small black spot which became no clearer in spite of long waiting. When the finger was removed the eye returned to its proper place, but for hours after it remained more deeply in the socket than it had been before the investigation. This retraction movement took place independently of the position of the other bulbus.

By combining a number of partial observations, only the following particulars could be made out: a very strongly curved cornea, a considerable mobility of the blackish brown iris which reacted promptly to light, an indistinct radial striation, and a circular pupil.

The use of the ophthalmoscope seemed at first to be attended with no results, for nothing but a deep black was visible. Then at a chance motion of the dugong's eye the small, round rose-colored papilla or the disc of the optic nerve came in sight. Thereupon further exploration of the retina was made though without additional results. The entire area of all four quadrants consisted of a deep black continuous tapetum nigrum in which no details could be made out, as is likewise true to some extent in case of the ventral portion of the fundus of the horse. In order to perceive clearly the few extremely delicate capillaries that radiated to the tapetum from the upper rim of the disc required an increase of the observer's myopia from 2½ to 5 dioptria from which may be deduced the degree of short-sightedness of the animal when out of water. The refraction of both eyes was the same.

It is noteworthy that the dugong also exhibited a certain dislike for bright light. At least one may so conclude from the eagerness with which it sought the shadow cast by the hull of the cutter.

In the manatee the pupil is round in life, but is transversely oval when the animal is dead (Murie, '80, p. 24). The dugong's pupil did not change shape after death. As in the manatee the nictitating membrane is well developed and freely movable. The eyelids are contractile and can be brought together until there is only a small slit, 12 mm. long, that remains not quite closed. The complete isolation of the bulbus from the exterior is effected by the nictitating membrane and the periorbital fat. The lids when closed are deeply wrinkled in a radial fashion, on account of the very strong orbicular contraction. This fact disposes of Pütter's (:03, p. 369) assumption based on the study of an embryo dugong whose eye slits were 5 mm. long and 3 mm. broad, that the eye lids as in case of the whales cannot be opened nor approximated. The copious secretion of the conjunctival sac has already been mentioned. In our captive the string of slime was of the consistency of the white of an egg, was as thick as one's finger, and flowed over the entire eye and down to the ground. That this secretion might be due to the irritation caused by the atmospheric air or the unaccustomed light immediately suggested itself, but in all the animals taken the secretion was similar without any difference in regard to mass, thickness, consistency, nor transparency and thus possessed properties not present in a catarrhal flow. The corneal reflex was easy to demonstrate and the eye lids were always held open.

The eyes of the dugongs that were dead when taken, were always injured even if they had hung in the nets only six or eight hours. In such cases there were uneven scratches with finely serrated edges, spreading superficially or even onto the membrana descemeti. They were always interior to the poles of the cornea, which lay free in death. The lens usually showed star-shaped to diffuse whitish cloudy spots that generally became more pronounced the longer the body was allowed to remain in the water. These spots were doubtless phenomena incident to death. The secretion of so great a quantity of slimy viscous matter from the conjunctiva is a protective adaptation to keep the surface of the eye from injuries from the sea water or its plankton fauna. If the slimy covering fails then the bulb of the eye is without protection. In this way are caused the scratches above mentioned, of whose traumatic nature there can be no doubt. In some specimens this even results in the eye lids becoming so abraded that they bleed freely.

The presence of a slimy protective coat for the eye has also been demonstrated for the whales, only in them it is not watery and mucous as in the dugong, but oily for otherwise it would be too easily washed away by the sea water (Pütter, :03, p. 370). Thus in the Cetacea a change of function has taken place in the glands of the eye as an adaptation to the conditions of aquatic life, and their products are likewise changed.

The copious secretion of mucus from the dugong's eye has long been known to many of the islanders of the Malay archipelago. All sorts of fantastic tales are associated with the so called dugongs' tears, in regard to their use as a powerful charm. Brandt ('69, p. 274) speaks only of the young dugong's shedding tears and that these were carefully gathered because they aroused in the possessor an affection as strong as that of the female dugong for its young. This belief was taken advantage of by the German and French perfume makers in order to assure a better market in Java for their perfume imported under the name of "dugongs' tears," "ajer mata doejoeng" (Dexler, :05, p. 200).

In contrast to the senses hitherto mentioned, that of hearing appears to be very well developed in the dugong. Both in the water and on the land the animal seemed to be much more affected by sound impressions than by those of sight. The dugong lying on the beach winced considerably at a sharp squeaking sound made by drawing in air between the puckered lips, as do also the guinea pig and the mouse. Only after numerous and quickly repeated stimuli of this sort did it remain motionless. Whether its ear was acoustically over sensitive with the absence of water pressure could not be determined. Nevertheless some sort of a stimulating influence is within the range of possibility since the meatus acusticus externus de norma transmits the pressure of the water to the ear drum. Also in the great size of the ear bones is seen an adaptation for hearing under water and not in the air, just as in whales (Boenninghaus, :04, p. 282). Evidence for keenness of hearing in the dugong is also found in Finsch's statement to the effect that in setting out the hunting-scaffolds for capturing the dugong, one must work with great care since the slightest rattling of these is said to be enough to frighten the animals away. Also in harpooning them one must proceed with absolute silence (Fairholme). Dexler's fishermen gave the floats of their nets a wedge-shaped form in order, as they claimed, to obviate the slight noise produced by the waves in striking floats of any other shape, and so frightening the animals away. But as a matter of fact the dugongs were rather frequently captured when the floats splashed loudly.

Besides the sense of hearing, we must also accord a fairly good development to that of cutaneous sensibility. The large upper lip appears to be very richly provided with nerves of feeling and as is evident from its anatomical construction, it is especially adapted for a manifold touch function, a fact that is of the greatest importance in the procuring of food. Apparently it serves in some degree to offset the seemingly poor eyesight, so that the animal in its wanderings over the beds of seaweed may be acquainted of the presence of blocks of coral, stones, and the like. The finely developed sense of touch in this organ is also shown by the fact that it was never found to be injured, in contrast to the skin of the rest of the body.

The presence of numerous scars and scratches on the skin of the back and sides of the body is characteristic of the dugong. As to their origin one can only guess. A very small portion of them may be set down as due to the wounds from the tusks of the males. Even in the oldest of 25 specimens examined, these tusks projected only 32 mm., and on their median sides they were almost entirely covered by the palatal processes. They are therefore very poorly adapted for making wounds. Possibly the animals wounded themselves in their endeavors to scrape off clinging parasites. The fishermen give a different explanation: they maintain that they have often seen the dugongs while at play, wound their backs on stones and corals as they rolled or swam about on the bottom. They thought the dugongs did this particularly over beds of Pinna shells, but it was impossible to determine this point.

There is little to be said in favor of the much discussed intelligence of the dugong. We have thus far seen no convincing evidence for according a particularly high degree of acuteness to a single one of the animal's senses. The senses of hearing and touch may be deemed the most highly developed; then, in a descending series, sight, taste, and smell. But even the keenness of hearing accorded the dugong cannot be compared with that of a really very keen-eared animal; otherwise the fact would be inexplicable that it is possible, though rarely to be sure, at times to sail up to feeding dugongs. When Dexler saw the herd of dugongs, previously mentioned at Moreton Bay, his men were rowing with splashing oars and without particular precaution. It must also be recalled that the often emphasized sound stimulus in water may frequently be communicated by the sensitive skin and mucous membranes of the head as well. The other senses, as before mentioned, are much less well developed. Considering the manifestly slight capabilities of the peripheral sense organs, it can hardly be concluded that the central nervous system has reached a high state of development. In fact, the brain of the dugong is not only relatively small — $\frac{1}{400}$ to $\frac{1}{600}$ of the weight of the body — but as we shall show in a later paper, it is so lowly organized that only a comparatively slight degree of intelligence may be presumed in this animal. A further proof of the stupidity of the Sirenia is found particularly in their behavior towards enemies, in their defencelessness, and in the ease with which they may be killed and exterminated.

Another question which we will here treat at further length is that of the use of the flippers. While on the one hand it is assumed (Freund, :04, p. 346, and elsewhere) that the flippers of the Sirenia are used as paddles and balancing organs, on the other hand it is supposed (Abel, :04, p. 186, etc.) by way of explaining certain anatomical changes, that their function is that of supports. In the dugong, particularly in case of the specimen that lay on the shore, one could clearly see that movement from place to place in the water was accomplished solely by means of the caudal fin. The pectoral limbs were held motionless at the sides, and directed backwards. If one endeavored to roll the dugong over on its side, it began to strike out with its tail but allowed its pectoral limbs to remain where they were. Active movements of the flippers for the purpose of locomotion on dry land were not observed.

There has been very little recorded as to the movements of the dugong on dry land in general, where a use of the appendages in locomotion is to be presumed. Klunzinger makes only the indirect statement that in the northern part of the Red Sea they are frequent in winter especially in December and January, and that otherwise they seldom go to the land. Finsch (:01, p. 10) speaks of an account by Leguat who was led to Rodriquez, in 1691, mainly on account of a dugong that was seen lying on the shore. Still, in Finsch's opinion this was a stranded animal since the dugong does not voluntarily go onto the land, and moreover has nothing to seek there. If a dugong be captured and thus forcibly brought to land, it may live 24 hours he was told by old Kabury on Palau. This observation is corroborated by that on our dugong which passed an even longer time — 48 hours — on land. It appears therefore that the dugong has not been actually observed to come out onto the land of its own accord, and in our opinion such a procedure is out of the question since the pectoral limbs are insufficient to enable the animal to do this. In no wise can it be established, as Brehm would have it, that "one can at least assume that those dugongs that have been seen lying on the shore were left by the ebb tide and were too sluggish to push their heavy bodies into the water again, preferring rather to wait quietly the next flood tide." They are simply incapable of using their anterior limbs, even as supports, on dry land. The possibility still remains that they support themselves on their flippers while gathering their food in the water. But against this supposition, in the first place, are their observed manner of feeding and the so called dugongs' tracks. In the second place, the difference in specific gravity between the animal's body and the supporting medium, cannot, in view of the considerable mobility of the dugong, be such as to entail any great burden on the limbs. Thirdly, the slender form of the appendages, their relatively small size, and finally the uninjured epidermis on the parts in question, furnish evidence against their use as supports in the water. Also in the case of the manatee, here adduced for comparison, the use of the flippers as organs of support is denied rather than maintained. Moreover, Brandt cites three authors who conclude from the manner of capturing the American manatee, that it is incapable of getting back to the water (by the aid of the limbs) if left up on the dry land. Garrod ('77, p. 139) says very decidedly that his manatee seemed *wholly unable to move either forward or backward on the land.* It made use of the limbs in sidewise movements only, at the same time twisting the body and tail. Chapman ('75, p. 461) and Murie ('80, p. 26) observed that their manatees swam quietly about at the bottom of the aquarium with the body sharply bent and the head and tail pointed downwards. Neither author says a word about their supporting themselves on their flippers, and Murie figures the animal in the posture described, with the limbs hanging down. He mentions their aid only in the taking of food. Brown ('78, p. 296) brings up still another argument against the possibility of a manatee being able to leave the water by aid of its flippers, namely the weakness of these organs, and his investigations into this matter also resulted negatively. Crane ('81, p. 457) makes a similar statement, basing his opinion on the generally clumsy movements of the animal when on dry land as well as on certain other considerations. Opposed to these observations are only the statements of Cunningham ('70) and Noack ('87, p. 299). The former saw a manatee support itself above the water by its flippers in order to crop the grass at the edge of the shore. This was done in such a way that one limb rested upon the shore. The latter author goes still further, for he states that the manatee is able to come out and move about on the land. "The animal (*M. senegalensis*) can actually move from place to place, though in a hobbling and unsteady manner. In so doing it supports itself on its wrists [!] and the outer edge of the forwardly directed hands, moving them alternately, and thus it progresses forward, though slowly, wriggling its body as it goes." But one may also suppose that the wrigglings of the body were the primary and locomotor movements, while the motions of the flippers might have prevented the body from falling over. In any case the position of these limbs as described is very remarkable! Noack relates that his manatee while in the water used its flippers to remove from its mouth pieces of bread that had proved too large. But as for a supporting function of these organs while in the water, Noack likewise knew of no evidence.

To sum up, it must be said, then, that scientific observation on the sea cows (for in case of the rhytina, also, Steller mentions that they are unable to move about on land) has hitherto produced but slight evidence that would permit us to assume so considerable a use of the flippers for body-supports as would explain the development of many anatomical details. Nevertheless, theoretically one may suppose it has only chanced that the use of the limbs as supports has been so seldom seen. But on theoretical grounds also, considerable objection may be raised against the evidence brought forward by Abel (:04, p. 166) as has already been done in the course of this discussion. We should remember that the Sirenia have arisen from air-breathing land forms of Mammalia; further we should not forget that their terrestrial type, with its adaptations of the body to pressure and weight, is greatly modified by adaptations to an aquatic life. Thus as we trace the evolution of the Sirenia, their mechanical adaptations to terrestrial life will be less and less noticed while those for aquatic existence will increasingly force themselves upon our attention. In like manner the anatomical changes brought about by these adaptations show the same progression. Such convergent anatomical changes in animals of the same biological environment are due to the influence of identical causes. In the case of these water mammals where proof of such changes is impossible to-day, we need not always assume different causes; here the same causes were acting on different objects (*e. g.*, Cetacea and Sirenia) and therefore it is conceivable that the same causes may bring about different results.

The dugong is the host of great numbers of parasites, both external and internal. On its back, as with whales, numerous barnacles establish themselves; a few Balanus but mostly Chelonobia. Internally, at the opening of the inner nares, on the dorsal surface of the velum palatinum, but particularly in the Eustachian tubes of both sides, were found numerous leaf-shaped trematodes from 3 to 5 mm. long clinging to the membrane in a mass of an hour-glass shape. These must have been identical with the *Opisthotrema cochleare* described in 1884 by Fischer. He had received them from Semper (of Würzburg) who collected them in the Philippines from the tympanic cavity of the dugong. Leuckart also, in 1875, described a trematode from the Eustachian tube of the dugong under the name of *Monostomum dujonis*. Von Linstow ('78) considers both forms as probably identical. The favorite habitats of these trematodes give, we believe, an indication of the path by which the infection has spread in case of the dugong, namely, from the nose, to pharynx, Eustachian tubes, and tympanic cavity. To be sure, Boenninghaus (:04, p. 259) has controverted the idea that in case of the parasites of the whale's ear the path of infection has been through the pharynx and the Eustachian tubes. He himself mentions a nematode, *Pseudalius minor* Kuhn, from the ear cavity of Phocæna. Moreover, von

Linstow records *Strongylus arcticus* Cobb from the ear of the beluga, and *Pseudalius alatus* from the Eustachian tube and the pharynx.

In the alimentary tract of the dugong, trematodes occur in the gut and the cæcum. In the small intestine some very large worm masses were observed, whose composition could not be fully determined. In addition, a species of Ascaris has long been known from the digestive tract and numerous specimens of this were also found in the glands of the stomach. It is *Ascaris halicoris* Owen, also wrongly called *Ascaris dugonis* Brandt. Whether the Ascarid seen by Steller in the rhytina is identical with that found in the dugong cannot now be determined. Two endoparasites are also described from the manatee: a nematode, *Heterocheilus tunicatus* Diesing, and a trematode, *Amphistomum fabaceum* Diesing (von Linstow, '78, '89). Chapman ('75, p. 456) found the large intestine of his American manatee filled with the latter.

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